Health Effects of Air Pollution in Southern Europe: Are There Interacting Factors?

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Recent results suggest that adverse health effects of air pollution exist at levels of pollutants around or even below air quality standards set by national and international institutions. Furthermore, there are indications that air pollution effects on health may be partly determined by specific mixtures of air pollutants and may be altered by other environmental, behavioral, and social patterns. Southern European countries share some common characteristics in terms of climate, geography, and life activity patterns. Results from studies undertaken in France, Greece, Italy, Portugal, and Spain investigating short- and long-term air pollution health effects are presented and their consistency demonstrated. These results provide adequate evidence that health effects—particularly short-term—of the currently measured urban air pollution levels exist. However, information available so far does not allow an assessment of regional differences in the health effects of air pollution as far as the Mediterranean region of Europe is concerned. It is suggested that the interaction between the traditional pollution (mainly characterized by high levels of black smoke and SO_2) and photochemical pollution must be investigated in this area, as well as the possible interaction between air pollution and high temperature and other meteorologic factors. In addition, measurements of individual exposure to different pollutants, affected by the pollutant's levels in specific microenvironments and the individual's time–activity pattern, must be undertaken for a better understanding of the air pollution–health link. Finally, the importance of the reported air pollution health effects in terms of public health must be addressed more closely. — Environ Health Perspect 103(Suppl 2):23–27 (1995)

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Introduction

Air pollution has been recognized as a health hazard since the early decades of our century, when severe air pollution episodes followed industrialization in northern Europe and North America (*1*). Interna-tional standards on air pollution quality have been based mostly on studies that followed these early air pollution episodes (*2*). Since that time, specific legal and control measures have been taken, resulting in substantial reduction of the air pollution levels in most developed countries (*3*). The reduction, however, has not been uniform in Europe; actually an increase has been observed in some areas, coupled with changes in air pollution mixtures toward more pronounced photochemical components (*4,5*).

Results of recent studies suggest that there are adverse health effects, even at today's medium and lower levels of air pollution (*6–10*). Furthermore, there are indications that air pollution effects on health may be partly determined by specific mixtures of air pollutants and may be altered by other environmental, behavioral, and social factors (*11–13*).

Southern European countries share some common characteristics in terms of climate, geography, and life activity patterns. Air pollution is a problem in these countries, especially in large urban centers,and several studies from such areas have recently reported results in air pollution epidemiology (*6–8,13–15*). To collectively evaluate this evidence, a workshop was organized in Athens, within the framework of the commission of the European communities' concerted action on air pollution epidemiology, in October 1992 (*16*).

The specific objectives of the workshop were: to review and specify the air pollution situation and its health effects in southern European areas; to explore and discuss methodologies for the study of synergy between pollutants and other environmental factors; and to assess future research needs.

This presentation is based to a large extent on the proceedings of this workshop.

Review of Studies on Air Pollution and Health from Southern Europe

Short-term Effects

The short-term effects of air pollution on health using several air pollutants as exposure measurements and different health outcomes, have been studied in Athens, Barcelona, and Marseilles. These temporal (or time series) studies have used daily data and modeling techniques to assess the health effects of air pollution.

Table 1 shows values for smoke and sulfur dioxide for Athens and Barcelona and the proportion of days that these levels exceed the World Health Organization (WHO) air quality guidelines for Europe (*2*). It can be seen that the yearly means for SO_2 are slightly above the WHO guideline, while for smoke they are well above this guideline, at least in Athens. However, levels for Athens are those measured by the monitoring station giving the highest values (near an urban road), while for Barcelona they represent the mean of 17 monitoring places (*8*). The study in Marseilles was based on older data (1974–1976) and for this period the yearly mean for sulfur dioxide was 50.7 $\mu g/m^3$ and for suspended particles (gravimetric method) 126.4 $\mu g/m^3$ (*7*).

Mortality Studies

The first analysis for the Athens data using daily total number of deaths as the outcome measure and sulfur dioxide and smoke as air pollution indices, covered the 8-year time period 1975 to 1982. A statistically significant effect of SO_2 (but not of smoke) on mortality was detected (*6*), which in a subsequent analysis of cause-specific mortality was attributed to deaths

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Table 1. Levels of air pollutants in two Mediterranean cities.

City	Sulfur dioxide, 24-hr average, µg/m^3		Black smoke, 24-hr average, µg/m^3	
	Yearly mean	Days exceeding 125 µg/m^3, %	Yearly mean	Days exceeding 125 µg/m^3, %
Athens[a]	66.7	10	141.5	52
Barcelona[b]	56.5	4	72.9	19

[a]Data from 1985–1990. [b]Data from 1985–1986.

from respiratory causes mainly among the elderly (*15*). Thus, the relative risk of dying from a respiratory cause for a person 75 years old or more, on a high air pollution day compared to a relatively "clean" day is 1.17, while for all causes the corresponding figure is 1.01.

Analysis for total number of deaths during more recent years (1984–1990), using a restructured monitoring network measuring at different locations than before, indicated similar results, especially for the winter season and for all the air pollution indices measured (i.e., SO_2, smoke, CO, NO_2). This analysis was done using log-transformed values for number of deaths and air pollutants and indicated that for 100% increase in smoke there is a 7.5% increase in the number of deaths. Mutual control of the different pollutants resulted in statistically significant effects only for smoke and SO_2 (*17*). A different analysis indicated that during extremely hot days in Athens there is interaction between high temperature and air pollution in their effects on health (*13*).

All the above results were obtained after control for meteorologic variables (temperature and humidity), season, and other chronological variables (month, day of the week, and holidays).

A study in Marseilles concerning total and cause-specific daily number of deaths data for 1974 to 1976 reported a statistically significant effect of SO_2 (but not of suspended particulates) pollution on mortality from respiratory causes among people 65 years of age or over (*7*).

Hospital Emergency Admissions

A registry for respiratory hospital emergency room admissions was established in Barcelona and this allowed analysis of the daily number of admissions in relation to air pollutant levels for 1985 to 1989 (*8,14,18*). Using a time-series modeling approach it was found that an increase of 25 µg/m^3 in SO_2 was associated with an adjusted increase of 6%, on the average, in emergency admissions for chronic obstructive pulmonary disease (COPD) during the winter and 9% during the summer. A similar association was found for smoke only for the winter. A threshold level was placed around 55 µg/m^3 for SO_2 and 80 µg/m^3 for smoke. Photochemical pollution, although relatively high in the summer, was not related to emergency admissions for COPD. However, there was suggestive evidence that high NO_2 levels interacted with soybean dust affecting the occurrence of asthma epidemics.

A study was done in Athens using data for daily emergency visits and admissions for cardiac and respiratory causes in 1988. The association of the emergency visits and admissions with smoke, NO_2, and CO was investigated with a multiple linear regression model. An increase of 16% per day in the number of respiratory admissions for an increase of 200 µg/m^3 in smoke was observed along with a corresponding 14% increase in cardiac admissions. Similar figures were observed for the other pollutants. These were statistically significant, while the observed increase for the total number of visits (6%) was not statistically significant with all air pollution indices (*19*). It can be seen that as the outcome becomes more specific and better defined, the percent change increases.

An effort has been made to assess the relationship between air pollution and COPD hospital emergency visits in the Oporto area in Portugal. Although only crude correlations were calculated, there seems to be an indication of increase in COPD emergency cases, especially during the winter (*20*).

Panel Studies

In the Gardanne coal-basin (mainly characterized by SO_2 pollution) study in the Marseilles area, panels of children were followed for a short period in highly polluted and less polluted communities. Associations of respiratory and other symptoms with daily levels of SO_2 were found in the more polluted communities but not in the less polluted ones (*21*).

Long-term Effects

Studies of long-term effects of air pollution on health usually compare exposed to non-exposed groups of subjects. These are either geographically defined (i.e., comparison of populations living in "clean" and polluted areas) or defined according to occupation (e.g., taxi drivers). There have also been some analytical epidemiologic studies, i.e., cohort or case–control. The long-term effects usually studied concern lung function and respiratory symptoms, chronic obstructive pulmonary disease and lung cancer.

A number of cross-sectional studies (some repeated in the same populations) have been conducted in Italy (*22*). It has been shown that in urban and in industrialized zones the prevalence of respiratory symptoms was consistently higher than in the corresponding rural areas.

In the Marseilles area in France, several studies were conducted in the 1980s. In the Gardanne coal-basin study it was found that among children prevalence of respiratory symptoms was higher among those living in the polluted area, while among housewives both respiratory symptoms and spirometric abnormalities were more prevalent among those living in the polluted than in the "clean" area (*23*).

A case–control study on the risk of chronic obstructive pulmonary disease was conducted in Athens in 1984 based on 200 cases and 400 controls. It was found that people living all their lives in Athens, compared to those who have lived in rural areas had a 2-fold higher risk of developing the disease independently of smoking habits and other confounders (*24*).

A case–control study of lung cancer, tobacco smoking, and air pollution was also undertaken in Athens (*25*). It was a small- scale hospital-based study (101 cases and 89 controls, all residents of Athens, were included). In this study, an attempt was made to use available monitoring network measurements of air pollution to assess individual past exposure. Air pollution levels were found to be associated with increased risk for lung cancer, but the relative risk was small and not statistically significant. However, when both air pollution and duration of tobacco smoking, as well as their interaction, were introduced in a multiple logistic regression model, the interaction term was significant at the suggestive level of $p = 0.10$.

In the Cartagena region of Spain an attempt was made to specify cancer incidence (particularly lung and bladder) by region and to compare these patterns in relation to air pollution levels. The authors report higher incidence in the most polluted areas, but the results are not very clear since there is no control for relevant confounders (*26*).

In Rome a number of retrospective cohort mortality studies on groups potentially exposed to urban air pollution are on-going, but preliminary results indicate no effect of exposure to air pollution on lung cancer among taxi drivers, urban policemen, or gasoline station attendants (*27*). However, there are difficulties in assessing effects due to lack of adequate data on exposure and confounders; small *ad hoc* studies are being undertaken to improve the level of knowledge.

Discussion

The above review indicates that research done so far does not allow an assessment of regional differences in the health effects of air pollution as far as the Mediterranean region of Europe is concerned. The results provide adequate evidence of health effects —particularly short-term—at levels lower than the currently established air-quality guidelines or safety limits (*2*). However, similar results have been published recently from other areas, mainly from northern Europe and the United States (*9–12,28*).

Scattered indications exist that air pollutants interact among themselves. This is plausible, since a given toxic substance may inhibit or potentiate the absorption, clearance, or biotransformation of another pollutant (*29*). Interactions of ozone and PM_{10} (*12*), SO_2 and smoke (*8,29*) and ozone and SO_2 (*30*) have been reported, while in other studies, although there were measurements, no attempt was made to study interaction (*29*). The study of interactive effects of multiple exposures complicates the analyses and reduces the statistical power. To address this important issue, one must design a study with more accurate exposure measurements and reduced exposure misclassification. Furthermore, measured air pollutants may be only indicators of unmeasured substances. An important characteristic of the Mediterranean areas, namely intense sunshine, enhances photochemical pollution. When referring to air pollution in this specific region, it is often implied that the study of photochemical pollution is most appropriate (*5*). However, results of studies on health effects of air pollution uniformly report associations of health effects with "traditional" pollutants (i.e., SO_2 and black smoke) that are found in moderate levels in some urban centers around the Mediterranean. Actually, these areas may be most appropriate for studies designed to test the interaction between particulates and sulfur dioxide on the one hand and photochemical oxidants on the other.

Another important issue on which there are few results so far is the possible interaction between air pollution and meteorologic factors, mainly temperature. There is weak evidence from epidemiologic studies that high temperature interacts with relatively high air pollution levels (*12,13*) and the same is true for particularly low temperatures (*11*). While few studies have addressed the issue of interaction, all studies use temperature data to control for confounding effects. This may happen because in most places extreme cold or hot temperatures do not happen often enough to allow for such an investigation. There are results indicating possible biological mechanisms for these interactions: it may be that sensitive individuals stressed by extreme temperature would respond to lower levels of air pollutants than otherwise. These results come mainly from experimental studies and show an increase of the effects of bronchoconstricting agents on lung function in asthmatics after exposure to cold air and increased effects of ozone exposure with increasing temperature (*31*). Since few studies have addressed these questions, it is suggested that southern European areas are appropriate for the study of synergy between air pollutants and high temperatures.

A third aspect concerning interactive factors is equally important. Climate affects not only temperature and humidity levels but also population activity patterns. If data are not available on time allocation, on level of activity, and on air pollution levels in different microenvironments, then answers to these important questions cannot be provided. Thus, if adverse air pollution health effects are more pronounced when high temperatures occur, is this a result of air pollution–temperature interaction or is it a result of higher individual exposure based on modified activity patterns? On this subject there is almost complete lack of appropriate data on both aspects that are important: time–activity patterns in the populations of interest and levels of pollutants in crucial microenvironments (including means of transportation and indoor/outdoor relationships) (*32,33*).

An open problem in air pollution epidemiology that becomes important in the comparative study of results from different regions is comparability of the absolute levels of measured air pollutants. So far, the criteria for monitoring sites have been poorly defined and few attempts have been made to discuss and standardize monitoring-place selection. This is very important, since air pollutant concentrations vary substantially between locations that are not geographically remote. Many studies use and report measurements of air pollution from fixed site monitors; and although these are internally valid for specific analyses, they are not adequate for comparisons between places. The problem is bypassed when personal monitors are used for assessing exposure, but this is not always possible. This issue is a difficult one that must be addressed however, since there is a need for synthesis of information on a regional and global scale.

It is often stated that air pollution at a given area has a major source, e.g., motor vehicles or industry. However, when describing sources of air pollution, one is forced to report percentages of emissions of specific pollutants that come from the three major sources: motor vehicle traffic, industry, and central heating. It may be useful, for comparative purposes, to calculate a composite index of the contribution of each source taking into account the actual levels of each pollutant in the atmosphere of each area of interest.

Finally, the most important question in air pollution epidemiology will have to be addressed: what is the public health importance of the converging results that air pollution health effects exist below what are today accepted as limits by national and international institutions?

The health effects of air pollution, even if they only slightly increase the risk to an individual, are likely to be important for public health because of the ubiquitous exposure of the population. However, the evaluation of their significance involves a more interdisciplinary approach, which may be affected by regional or local characteristics.

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